

# Modelling the Processes of Taking Over the Watch From an Autonomous Navigation System

S. Hochgeschurz, E. Dalinger & F. Motz  
*Fraunhofer Institute for Communication, Wachtberg, Germany*

**ABSTRACT:** The maritime industry is striving towards increasing levels of autonomy within the field of navigation. However, fully autonomous vessel navigation requires an extraordinarily complex system. As a step towards full autonomy and to reduce system complexity, nautical officers should still be available on board to take over the watch from the autonomous system in situations, in which human intervention is required. Therefore, a highly advanced human-machine interface (HMI) is essential, which supports nautical officers in retrieving all necessary information in order to manage the takeover. The implementation of the autonomous system and introduction of an HMI creates new processes, which need to be defined. In this paper, we portray our approach to define the processes for watch handovers from the autonomous system to nautical officers by investigating current watch handover processes. Subsequently, the resulting process models are described and discussed.

## 1 INTRODUCTION

Recent developments in the maritime industry suggest a trend towards increasing autonomy, just as in the automotive industry [9]. Autonomy is defined as a certain degree of self-governance, i.e., a ship that is autonomous can operate independently of humans to a certain extent according to the degree of autonomy it possesses [16]. Increasing autonomy likely results in numerous benefits. First, increasing autonomy has the potential to reduce the burden on humans by relieving them of difficult, attention demanding, and stressful tasks [18]. Opposed to humans, a system does not suffer from limited attention spans or fatigue when performing a task for an extended period of time. Therefore, increasing autonomy likely increases overall safety in shipping by preventing human deficits from causing accidents [15, 18]. Lastly, increased autonomy can improve efficiency in the use of limited resources and thus has

a positive impact on the environment [1], while simultaneously reducing costs [13].

### 1.1 *Constrained Autonomy*

Fully autonomous vessel navigation without nautical officers who potentially intervene requires an extraordinarily complex system [16]. As a step towards full autonomy and to reduce system complexity, nautical officers should still be present on board to take over the watch and navigational control in situations, in which the autonomous system requires human intervention. This so-called constrained autonomy (see [13]) requires the definition of an operational design domain (ODD). The ODD precisely defines system boundaries (e.g., specific traffic situations or weather conditions), within which the autonomous system can operate safely [4]. Since the autonomous system is able to

detect when the ODD is left, the nautical officer can pursue other tasks and does not necessarily have to be on the bridge. Thus, it is not the nautical officer's task to supervise the autonomous system while it operates within ODD limits. As a result, negative effects associated primarily with a supervisory role of humans, such as automation surprises [17], boredom or fatigue [18] are less likely to occur. When the ODD is left, the autonomous system calls the nautical officer to the bridge in a timely manner to take over the ship. Constrained autonomy therefore enables a periodically unmanned bridge meaning that the bridge is unmanned while the system is operating within ODD limits [16].

If the ODD is left and the nautical officer is called to the bridge to assume control, there is no human officer available to aid the officer of the watch (OOW) in gaining situational awareness (e.g., [5]) of the current navigational situation [15]. All necessary information must be retrieved from the autonomous system, since the OOW is unfamiliar with the situation, i.e. out-of-the-loop (e.g., [6]), when arriving on the bridge. If information provided by the autonomous system is insufficient, the OOW might misinterpret the system's intentions. Therefore, a highly advanced human-machine interface (HMI) is essential [18], to allow the OOW to retrieve all necessary information within the shortest possible time in order to manage the situation as efficiently as possible. To develop the HMI, a useful first step is to define processes that describe how watch handovers from the autonomous system to a nautical officer will proceed once the autonomous system is operational. The implementation of the autonomous system therefore creates new processes within the shipping company, which need to be developed.

## 1.2 Objectives

The aim of this paper is firstly to portray our approach to modelling the new watch handover processes by investigating current ones and secondly to describe and discuss the resulting handover process models. The handover processes were modelled as part of the B0 | B ZERO project, funded by the German Federal Ministry for Economic Affairs and Energy. The B0 | B ZERO project aims at developing a constrained autonomous system that can operate fully autonomously for up to eight hours, if the ODD is not left in the meantime. After eight hours have passed or if ODD limits are exceeded, the watch will be handed back to a human officer. This constrained autonomous system will be tested and implemented on a test ship owned by a collaborating shipping company.

## 2 METHODS

### 2.1 Process analysis

The processes of watch handovers from the autonomous system to human officers were defined using process analysis. Process analysis provides a review of an organization's work processes and fosters understanding of current processes within the

organization [2]. Further, process analysis helps to identify potential weaknesses and thus serves as a basis for process improvements [3]. It can also be used for process redesign if organizational developments, such as introducing new technologies, occur. When new technologies are introduced, new processes can be developed by first analyzing current processes and then adjusting these to meet the new requirements.

A process consists of a sequence of activities (process steps) in an organization, which are performed by organizational units in a predefined order with the goal of accomplishing a task [12]. A process receives input as information, matter, or energy, and produces several outputs [10]. To develop a process model one needs a method for data collection, a modelling language, which is a graphical representation used to specify processes in a model, and a modelling tool for digitizing the process model. There are several modelling languages available and a widely used standard is Business Process Modelling and Notation (BPMN, [12]). There are also diverse modelling tools available, which differ in functionalities available from modelling to simulation.

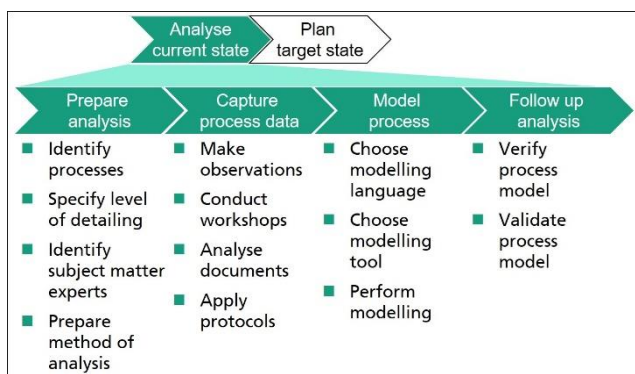


Figure 1. Analyzing the current state according to [8]

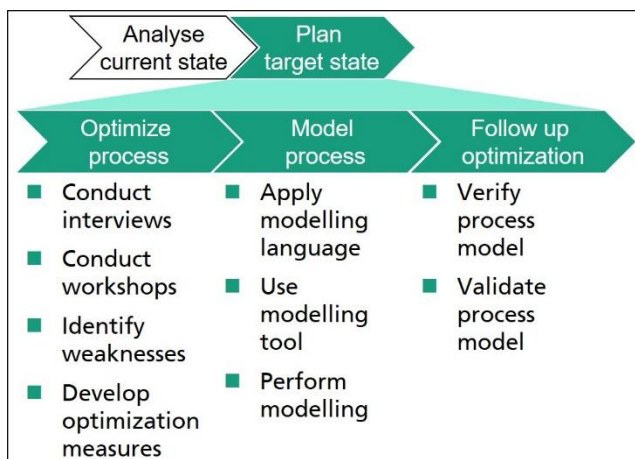


Figure 2. Planning the target state according to [8]

Process analysis can be conducted as follows according to [8]. Usually, the first step entails carefully preparing the analysis of current processes (Figure 1). This step comprises specifying the level of detail, i.e., defining the relevant processes and sub-processes to be considered, as well as identifying subject matter experts or process experts depending

on the processes under consideration. Next, the analysis method is specified by determining for example to what extent subject matter experts should be involved. In the second step, data is collected, which can entail several methods such as document analysis, observations, workshops or protocols. In the next step, the gathered process data should be transferred to a graphical process model. For this purpose, a suitable modelling language and modelling tool should be selected. A follow-up analysis is conducted, in which the process model is verified and validated to ensure its accuracy. To redesign current processes and plan the target state, the process optimization phase is conducted (Figure 2). In this step, weaknesses are identified and optimization measures are defined using interviews and workshops. Subsequently, the target processes are modelled with the modelling language and the modelling tool. Lastly, in a follow-up analysis, the target processes are then also verified and validated.

## 2.2 Procedure for redesigning processes

In the following, we describe the procedure we used for defining the processes of taking over the watch from the autonomous system. The procedure was developed based on the process analysis approach described in section 2.1 considering the requirements of the domain in question. This procedure can be used in similar use cases and adapted if necessary. Introducing new technologies can lead to significant changes in current processes. New processes need to be defined or old processes need to be adapted to meet the requirements of the emerging domain. Capturing the current processes and then considering which changes are necessary has proven to be a beneficial approach [3].

As a preparation for process capture, relevant processes in the area of redesign are identified at first. For this step, it is vital to consider the purpose of the new technology in order to understand what changes will arise for which reasons. To capture the processes, relevant subject matter or process experts should be selected. They need to meet certain requirements such as knowing the processes in question and having a certain experience within the respective domain. These requirements should be defined and communicated to the organization, whose processes are to be considered.

Data collection should be started with the analysis of documents describing the relevant processes, as long as such documents are available. After analyzing the documents, preliminary process models can be defined and used as samples for data collection during the interviews with process experts.

Since data should be collected with the modelling tool if possible, so selecting a modelling language and a modelling tool should be done in time. The process-modelling tool can be used to visualize the captured processes and thus provides the basis for a mutual understanding between the analyst and the process expert. Using the modelling tool during the interviews allow to make adjustments that the process expert can directly see. In this way, simultaneous verification and process capture is possible. If several process experts are interviewed

about the same process, the captured process models should be analyzed and aggregated. Afterwards, the resulting process models should be validated to check whether the processes conform to work specifications.

The next step is to define the target processes, namely, the future processes in the organization after the new technology has been introduced. This is done by analyzing and adjusting the current processes to the requirements of the new work domain. In particular, changes due to technical requirements should be considered. Hence, both the technical experts responsible for developing the new technology as well as process experts should be involved in developing the future processes. A workshop with several experts or interviews with just one expert can be conducted as a suitable data collection method. The current process models can then be adjusted during these workshops or interviews. The use of the modelling tool during the workshop ensures the mutual understanding among the experts and verification of the developed processes. If necessary, additional processes should be defined. In the final step, validation of the processes should be carried out with both the process experts as well as with the technical experts to guarantee that the processes conform to organizational regulations as well as to technological characteristics.

## 3 DATA COLLECTION

### 3.1 Identification of relevant processes

Before modelling the future processes, it is necessary to first identify the processes that need to be redesigned. With the introduction of a constrained autonomous system, a vessel can navigate autonomously as long as ODD limits are not exceeded [13]. In the various situations outside ODD boundaries, the system needs to call a human for help. The human then has to quickly take over the watch from the autonomous system in these various situations, representing processes that do not exist in traditional navigation and therefore need to be defined.

Leaving the ODD can happen either expectedly or unexpectedly (see [18]). For example, a constrained autonomous ship could be designed to handle deep-sea passages on its own (e.g., [15]), while it needs help from the human operator when entering shallow waters. In this case, the OOW knows in advance (i.e., when planning the voyage) when the vessel will require human assistance – namely before entering shallow waters. If the ODD exit happens unexpectedly, the OOW cannot predict when exactly this is going to happen. For example, it is not possible to anticipate exactly when a complicated traffic situation will occur. Detecting such a situation thus leads to an unexpected call for human intervention.

Since the OOW knows when the expected ODD exit is going to happen, he can prepare for it and come to the bridge in a timely manner to take over from the autonomous system. This seems to be quite similar to traditional watch-handovers between the

OOW to be relieved and the relieving OOW, where the relieving OOW also has no prior knowledge of the situations' specifics when arriving on the bridge. Standard watch takeover procedures as found in [11] and in checklists of shipping companies were therefore used to guide modelling the future process of a watch takeover after an expected ODD exit.

The unexpected ODD exit, on the other hand, is very similar to a situation during a traditional watch, in which the OOW calls the master for help. For example, the OOW has to call the master, when he or she expects danger to the ship because of the traffic situation [11]. The master then comes to the bridge, largely unaware of the situation asides from the information he or she received via the call. To take further action, the master first has to become acquainted with the situation at hand. The current process of calling the master (e.g., [11]) was therefore used to support defining the process of a watch takeover from the autonomous system after an unexpected ODD exit.

In both traditionally encountered situations, humans are initially out-of-the-loop and are then briefed about the situation by the current OOW similar to when the autonomous system detects that the ODD has been left and calls for a nautical officer. In the latter case, the current OOW is replaced by the autonomous systems itself. Therefore, these two current processes provide a good starting point to model the future processes of expected and unexpected watch takeovers.

### 3.2 Modelling of processes

The process models of expected and unexpected watch handovers in case of ODD exits were defined following the procedure described in section 2.2. Firstly, relevant current processes were defined and preliminary process models were created based on relevant documents. These were then further refined and validated in interviews with nautical officers and masters. Subsequently, in three workshops with nautical experts and developers of the autonomous system, the current process models were converted into process models for future operations with the autonomous system. The widely used BPMN [12] was used as modelling language and iGrafx as modelling software.

For the process of an expected watch takeover from the autonomous system, the standard watch handover between two nautical officers was selected as the relevant current process. The "watch handover" checklist of the shipping company providing the test ship was used as the relevant document. For the process of an unexpected watch takeover from the autonomous system, a situation, in which the OOW calls the master for help, was used as the relevant current process. Here, the procedure for calling the master (e.g., [11]) served as the relevant document. Since both current processes occur regularly and involve first officers and masters, the first officers and masters of the shipping company in question were selected as process experts.

A total of four process experts took part in semi-structured interviews conducted online due to the

coronavirus pandemic. Our goal in the interviews was to refine, verify and validate the current process models created on the basis of the relevant documents. For this purpose, the process experts were asked to imagine themselves in the role of the OOW to be relieved and tell us more about each step of the current processes. Follow-up questions were asked to obtain the following information, if the process experts did not already mention them themselves in their report:

- the order of actions during the process
- what information is used to perform the action
- the reasons for performing the action
- the person who performs the action

During the interviews the process experts could see the designed process models and applied changes. The process modelling procedure offered process experts an opportunity to give direct feedback and to verify applied changes to the process model. The process experts have all been employed as nautical officers for at least 12 years and two of the four experts additionally had experience as masters. To illustrate the current process of calling the master, several scenarios featuring different situations were defined. The participants were surveyed to frequently occurring situations when the master had to be called. Critical collision situations with a give-way target were mentioned as the most frequently encountered situations and were thus taken as an example to model the process of calling the master.

After the interviews, the resulting takeover process models were summarized and consolidated. They were then converted into process models for future operations with the autonomous system in a total of three workshops with technical experts, i.e., developers of the autonomous system and of an intelligent logbook. The resulting process models were finally coordinated with the shipping company in a further workshop to check whether they are fundamentally compliant with the company's specifications.

## 4 RESULTS

A total of three processes for future ship operations using the constrained autonomous system were defined. In the following, the constrained autonomous system will be referred to as the AutoOOW – an abbreviation for an autonomous officer of the watch. Whereas in the current processes the relieving OOW or the master and the OOW to be relieved are the process participants, in the processes defined, there are the following four process participants:

- the AutoOOW,
- the AutoOOW's HMI (AutoOOW-HMI), providing information from the AutoOOW to the crew,
- the intelligent logbook (referred to as AutoLogbook) – a mobile device intended not only for logbook keeping, but also for alerting and providing relevant information to the crew, and
- the OOW who is not necessarily on the bridge, but on standby in case the ODD is left unexpectedly (this could be the master in an emergency)

The AutoOOW-HMI and to some extent also the AutoLogbook largely adopt the former tasks of the OOW to be relieved specified in the current process models. With the help of the AutoLogbook, the OOW shall be informed, when he or she needs to come to the bridge to assume control. The AutoOOW and the AutoLogbook were included in the defined process models to point out the data exchange between the systems (see Figure 3). Taken together, the following three process models were defined:

- a process model for maintaining constrained autonomy, which contains the watch takeover processes as sub-processes,
- a process model for performing an expected watch takeover from the AutoOOW, and
- a process model for performing an unexpected watch takeover from the AutoOOW.

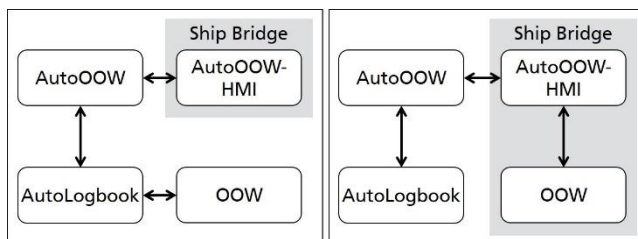


Figure 3. Data exchange when the OOW is not on the bridge (left) and when the OOW is on the bridge (right)

#### 4.1 Process for maintaining constrained autonomy

The process for maintaining constrained autonomy describes the general procedure of the information flow between the process participants during autonomous operation and during the changes between autonomous and non-autonomous operation. Thus, this process contains the two watch transfer process models as sub-processes and is therefore of higher order with respect to them. One important aspect of this process is to provide status information, which should be accomplished by both the AutoLogbook and the AutoOOW-HMI, ensuring that officers can retrieve the information regardless of whether they currently are on the bridge or not (see Figure 3). Status information includes information about the current state of the ODD (is the system inside or outside the ODD?), the AutoOOW (is the system currently operating autonomously or non-autonomously?), and the OOW (is the OOW currently on the bridge?). Both devices shall also provide summarized information about the current situation such as information about the weather or the own ship's voyage progress. Additionally, the AutoOOW-HMI shall provide sensor fusion results, i.e., results that contribute to a quick understanding and classification of the navigational and traffic situation.

The AutoLogbook shall further display current messages from the AutoOOW, informing the master or the OOW, when and for what reason a watch takeover is necessary and to summon him or her to the bridge. In addition, it shall be possible for the OOW or master to retrieve information from the AutoOOW via the AutoLogbook when the bridge is unmanned. Thus, the AutoLogbook serves as a means to maintain communication between the AutoOOW

and the OOW or master when the bridge is currently unmanned. Communication becomes especially important when ODD limits are exceeded. In case this happens, one of the watch transfer processes shall be initiated, which are described in the following sections. If the AutoOOW returns to ODD limits after the watch transfer, the AutoOOW can assume the watch again.

#### 4.2 Process for performing an expected watch takeover

Tasks of the AutoOOW-HMI and their consecutive order during the expected watch takeover from the AutoOOW can be derived from Table 1. Similar to the process for maintaining constrained autonomy, the process of the expected watch transfer from the AutoOOW to the OOW starts with providing a general overview of the state of the ODD, the AutoOOW, and the OOW. Then, the OOW shall check whether the AutoOOW is currently performing a maneuver. If so, the watch transfer is to be postponed. The check is followed by the OOW confirming his identity by logging into the AutoOOW-HMI. Additionally, the capability of the OOW to take over the watch shall be ensured. It must be still clarified, how this will be accomplished, since in the current process of a standard watch takeover this is done by a personal assessment of the OOW to be relieved. Formalities such as signing changes in master's (night) orders, completing checklists, and finalizing logbook entries were also included in the resulting process model. Checklists shall be completed automatically whenever possible.

An important task of the OOW to be relieved in the current process of a standard watch takeover is to inform the relieving OOW about the current navigational and traffic situation. During an expected watch takeover, the AutoOOW shall accomplish this by enriching a chart-based representation of the navigational and traffic situation with improved sensor fusion results. For example, references to relevant COLREGs (conventions on the international regulations for preventing collision at sea) currently in force shall be provided. Finally, the OOW shall complete the takeover process with the actual takeover by switching to non-autonomous operation.

#### 4.3 Process for performing an unexpected watch takeover

The process for performing unexpected watch takeovers from the AutoOOW refers to cases where the ODD was unexpectedly left due to some critical situation. The situation in which the own ship needs to act quickly to avoid a collision with one or more give-way targets was used to model the current process of a master calling procedure (as described in section 3.2). Therefore, it was also employed as a use case during the definition of the process for performing an unexpected takeover.

Table 1. Tasks of the AutoOOW-HMI during watch takeover processes

Expected watch takeover	Unexpected watch takeover
Provide an overview of status information including <ul style="list-style-type: none"> <li>– the ODD status</li> <li>– the AutoOOW status</li> <li>– the OOW status</li> <li>– crew instructions</li> <li>– the current situation</li> </ul>	Provide an overview of status information including <ul style="list-style-type: none"> <li>– the ODD status</li> <li>– the AutoOOW status</li> <li>– OOW-Status</li> <li>– the current situation</li> </ul>
Ask for confirmation of <ul style="list-style-type: none"> <li>– identity</li> <li>– capability to take over</li> </ul>	Ask for confirmation of <ul style="list-style-type: none"> <li>– identity</li> </ul>
Display changes in Master’s (night) orders and obtain the OOW’s signature	Watch takeover by the OOW or master
Provide ship status information including <ul style="list-style-type: none"> <li>– the status of connected bridge equipment</li> <li>– the engine status</li> <li>– work in progress on board and ongoing hazardous work</li> <li>– items with impact on the ship’s maneuverability</li> </ul>	Provide ship status information including <ul style="list-style-type: none"> <li>– the status of connected bridge equipment</li> <li>– the engine status</li> <li>– Items with impact on the ship’s maneuverability</li> </ul>
Provide navigation-related information including <ul style="list-style-type: none"> <li>– the navigational situation</li> <li>– the traffic situation with COLREG-related hints</li> </ul>	Provide navigation-related information including <ul style="list-style-type: none"> <li>– the navigational situation</li> <li>– the traffic situation with COLREG-related hints</li> <li>– the critical target</li> <li>– nearby navigational hazards</li> <li>– room available for maneuvers</li> <li>– weather, tide and currents</li> </ul>
Offer the possibility to search for additional information	Recommend a maneuver to solve the situation
Ask for completion of relevant checklists and logbook entries	Offer possibility to modify maneuver or perform a maneuver manually
Watch takeover by the OOW or master	Provide a review of the selected or performed maneuver

While the actual watch takeover shall take place at the very end of the expected watch takeover process, it is supposed to happen relatively early in the process of an unexpected watch takeover (see Table 1, which also provides a comparison of the two watch takeover processes). As in the respective current process model, the actual watch takeover shall occur comparatively early to allow the OOW to react quickly to the situation due to the anticipated time pressure. For this reason, several steps from the expected watch takeover process are omitted in the unexpected watch takeover process. Most of the omitted steps consist of formal procedures, which can be addressed after the critical situation has been resolved.

On the other hand, in unexpected watch takeovers, some additional steps are included that do not need to be performed during expected watch takeovers. One additional step is the AutoOOW-HMI providing detailed information about critical targets due to the impending collision situation. Such information comprises for example the targets’ CPA and TCPA values, their distances to the own ship, and their AIS information, as well as their position. Likewise, the AutoOOW-HMI shall provide information about the sea area available for avoiding the collision. Finally, the AutoOOW shall suggest one or more maneuvers to the OOW, taking into account the available sea area. The OOW shall then be able to select or modify one of the proposed maneuvers and subsequently either perform the proposed or modified maneuver or reject it to perform a maneuver manually. After the maneuver, the AutoOOW shall further provide the

possibility to evaluate the performed manoeuver. Once the critical situation is resolved and the system has returned to its ODD limits, it shall be possible to hand the watch back to the AutoOOW.

## 5 DISCUSSION

In recent years, a trend towards increased autonomy could be observed in the maritime industry [9]. However, since fully autonomous vessels are rather unrealistic in the near future [1], some form of remote control [20] or constrained autonomy as in the B0 | B ZERO project is initially pursued. A constrained autonomous vessel can handle most situations autonomously without any crew on the bridge, but requires human assistance in certain situations [13]. In these situations, the autonomous system must hand over the watch to the OOW. Watch handovers therefore no longer take place only from human officers to human officers, but also from autonomous systems to human officers – a new watch handover situation that does not yet exist and for which processes must be defined. The definition of the processes ultimately serves to produce a unique HMI that optimally supports the handover processes.

Within the B0 | B ZERO project, three process models for future operations with the autonomous system were defined: A process for expected watch takeovers, derived from the current process of a standard watch takeover between two nautical

officers; a process for unexpected watch takeovers, based on the current process of a critical situation, in which the OOW calls the master for assistance; and a process for maintaining constrained autonomy, which is superior to the other two processes and describes general procedures during autonomous operation and watch changes. This last process lacks an equivalent in the current processes and thus illustrates that processes can change fundamentally as a result of introducing new technologies. In general, it is anticipated that the process models created will be adapted as needed during the course of the project in the sense of an iterative procedure. The procedure used explicitly includes such iterations by incorporating many evaluation and validation steps in accordance with the human-centered design approach for interactive systems [7].

In the discussion of constrained autonomy and taking over the watch from an autonomous system, especially in unexpected situations, it is necessary to raise awareness of potential risks such as an approach entails. One of these risks is *skill degradation* – a phenomenon that has been frequently observed in the context of increasing system automation (e.g., [19]). The fact that the autonomous system will perform routine tasks almost exclusively can lead to skill degradation among operators, since not frequently used skills are likely to decline over time [14]. Therefore, it is immensely important that operators train their skills regularly [19] in order to be able to handle critical situations appropriately when called to the bridge. The expected watch takeovers from the autonomous system, for example when entering shallow waters, could be a way to reduce skill degradation by training the operators' skills. Furthermore, the risk of skill degradation reinforces the need for an efficient HMI that optimally supports the watch handover processes.

### 5.1 Approach

The goal of this paper was not only to describe the newly defined watch handover processes, but also to present our approach to defining these processes. Our approach included the conduction of online interviews in which process experts were able to see the current processes during process modelling. This approach had several advantages. First, process experts were given the opportunity to object if something was misunderstood, so that changes applied to the current version of the process model could be validated on the spot. This enabled the processes to be captured and verified at the same time. In addition, results from previous interviews could be used as a starting point for subsequent interviews, saving time and providing an additional validation and verification opportunity. The interviews further facilitated asking in-depth questions, allowing us to obtain a lot of information including the reasons why certain actions are taken and what specific information is necessary at certain steps in the process. Because interviews were conducted online, they were independent of the location of the interviews' participants. This was a big advantage, as most officers and masters from the shipping company providing the test ship for the B0 | B ZERO project, were not in the same country as the

interviewers at the time of the interview. For process analysis, it is important that the interviewees are process experts with respect to the processes within the shipping company that will implement the new technology and processes in the future.

The modelling language used proved to be easy to explain and easy to understand by someone without any prior process analysis experience. In our experience, it was particularly helpful to start the interviews with preliminary process models that were developed based on document research. In this way it was possible to explain the method and the components of the modelling language clearly with the help of a domain, with which the process experts are by definition very familiar.

The results show that the approach for modelling processes as described above can be applied in an emerging domain like autonomous shipping. The processes provide a thorough description of the emerging procedures on board and can be used for further investigations in the area.

### 5.2 Limitations

The original plan was to model the current processes by observing watch takeovers both in the simulator and on board the test ship. However, due to the coronavirus pandemic, neither simulator nor on board observations were possible, which is why the interviews and workshops were conducted online. Observations in this context have the advantage that they are to a certain extent objective [8], since they rely on observable behavior. Two observers who receive the task to write down all actions an operator performs to achieve a certain goal are very likely to take note of similar aspects. Therefore, such observations are independent of the observer. However, the procedure we used is rather subjective, since it is based on participants' introspections. People are not always good at reporting exactly how they perform a frequently executed activity, as they may not consciously recall all the steps the activity comprises [8]. This must be kept in mind when interpreting the results. It is further important to note the small sample size used to model the current processes. Additionally, it remains to be determined to what extent the processes may be generalizable to other shipping companies with different specifications and processes.

## 6 CONCLUSIONS

The foreseeable deployment of constrained autonomous vessels necessitates adapting existing watch handover processes to the new situation. With constrained autonomy, in contrast to traditional navigation, a machine instead of a human will hand over the watch to another human in most situations. The purpose of our paper was to describe our approach for defining processes of such emerging watch takeover situations and the resulting processes. Three processes were defined and provide insight into different aspects of the new situations. Our approach to defining the processes demonstrates that it is

feasible to define processes on the basis of online interviews when simultaneously presenting process models to process and technical experts. The defined processes can now be used as a basis for the design of the HMI of the autonomous system, enabling the HMI to be closely in line with the user's needs in the sense of a human-centered design process. Whether the HMI will then be as good as the nautical officer in handing over the watch is an interesting question for further research and remains to be investigated.

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